CH-TRU WASTE TRANSPORTATION SYSTEM

RAIL STUDY

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U.S. DEPARTMENT OF ENERGY
CARLSBAD AREA OFFICE
CARLSBAD, NEW MEXICO

U.S. DEPARTMENT OF ENERGY
NATIONAL TRANSPORTATION PROGRAM
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Table of Contents

List of Abbreviations/Acronyms

C of C	Certificate of Compliance
CFR	Code of Federal Regulations
CH	contact-handled
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
IAEA	International Atomic Energy Agency
INEEL	Idaho National Engineering and Environmental Laboratory
LSA	low specific activity
LWA	Land Withdrawal Act
NRC	U.S. Nuclear Regulatory Commission
RFETS	Rocky Flats Environmental Technology Site
SAR	safety analysis report
SME	subject matter expert
SRS	Savannah River Site
SWB	standard waste box
TEPTRAM	Ten Year Plan Transportation Model
TRAGIS	Transportation Routing Analysis Geographical Information System
TRANSCOM	Transportation Tracking and Communication System
TRU	transuranic
TRUPACT-II	Transuranic Package Transporter-II
WIPP	Waste Isolation Pilot Plant

1.0 Summary

The current Waste Isolation Pilot Plant (WIPP) transportation system is truck-only. This study examines the feasibility of shipping contact-handled (CH) transuranic (TRU) waste from four major U.S. Department of Energy (DOE) sites to WIPP by commercial rail. The study was conducted as an initiative requested by the Environmental Management Program Integration Executive Committee. The study is also associated with the Carlsbad Area Office Re-Engineering the Pipeline to WIPP initiative as part of the evaluation of the WIPP transportation system.

Based on documented risk analyses, both truck and rail shipments are safe but environmental impacts and risks may be reduced by using fewer total shipments through rail transport.

The existing packaging[1] for truck shipments of CH-TRU waste to WIPP, the Transuranic Package Transporter-II (TRUPACT-II), was used as a baseline case for comparison of rail and truck shipment systems. In addition, five alternative packaging concepts were proposed for consideration to supplement the existing transportation system. These concept packagings, along with the baseline case, were the bases of the comparison and cost analyses performed in this study.

Two independent models were used to evaluate and compare costs. The models were validated against each other and the results were in general agreement (±10%) with minor differences arising from differing assumptions built into the model(s). For the purpose of this study, it was assumed that applicable rules, regulations, legal requirements, and DOE commitments [e.g., commitment to use U.S. Nuclear Regulatory Commission (NRC)-certified packagings for transport of waste to the WIPP] would be met.

The results for the baseline case analysis using the TRUPACT-II show that the cost of commercial rail shipments for three of the four sites examined in this study, Hanford Site (Hanford), Savannah River Site (SRS), and Idaho National Engineering and Environmental Laboratory (INEEL), is comparable to the cost of truck shipments given the following: (1) The assumed rail carriage costs can be negotiated for an expanded volume shipment (28 TRUPACT-IIs per rail shipment), or (2) an additional reduction in rail carriage costs can be

[1] As defined in Title 10, Code of Federal Regulations, Part 71 (10 CFR 71), a packaging is considered the assembly of components necessary to ensure compliance with the requirements of Part 71; a package is the packaging together with its radioactive contents as presented for transport.

negotiated for a base case rail shipment (18 TRUPACT-IIs per rail shipment). Rail transportation feasibility is also improved as the number of TRUPACT-IIs per shipment is increased (within the constraints of practical package loading schedules at the sites and the maximum allowable shipping period for the TRUPACT-II). The results also show that a larger fleet of TRUPACT-IIs is required for rail transportation than is required for truck transportation.

The results for the alternative packaging case show that transportation costs are reduced for both truck and rail when a larger volume packaging is used. Also, the cost reduction is greatest when the largest packagings use the rail mode for transportation.

Conclusions – This report reaches the following conclusions:

- Although the cost of transporting TRUPACT-IIs by commercial rail[2] is found to be comparable to truck, there is not a sufficient cost differential to recommend rail at this time – the cost analysis is based on an assumed negotiated lower carriage cost

- Shipment of CH-TRU waste in TRUPACT-II packagings by commercial rail might be cost effective given three conditions:
  - rail carriage rates lower than the values in this report can be negotiated
  - a sufficient volume of waste can be transported per shipment
  - a larger fleet of packagings can be established

- Development of an alternative packaging is potentially advantageous in shipping CH-TRU waste to WIPP based on a reduction in the number of shipments required and the potential for transporting boxes of waste that are too large for the TRUPACT-II.

Recommendations – Based on these conclusions, the following three recommendations are provided:

- Develop a strategy to negotiate lower rail costs for transport of CH-TRU waste to WIPP, perhaps on a site-by-site basis since there are separate rail lines serving individual sites

- Identify the infrastructure (scope, cost, and schedule) necessary for rail shipments

- Continue development of an alternative packaging for shipment of CH-TRU waste by either rail or truck.

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[2] Shipment of CH-TRU waste in TRUPACT-II packagings by dedicated rail is not cost effective, based on information from previous reports and discussions with rail line representatives (see Section 5.0, Study Assumptions).

Appendices include a list of rail study participants (Appendix A), a list of previous truck/rail reports (Appendix B), an evaluation of existing packagings considered for WIPP shipments (Appendix C), a list of parameters used in evaluation of packagings (Appendix D), and a list of legal and institutional issues or requirements considered in the study (Appendix E).

2.0 Purpose

The purpose of the CH-TRU Waste Transportation System Rail Study is to examine the feasibility of using commercial rail to ship large quantities of CH-TRU waste from four DOE sites to WIPP. The study also examines the feasibility of using alternative packaging (other than the TRUPACT-II) for shipping CH-TRU waste by rail.

3.0 Scope

Transportation cost estimates for shipping TRU waste from four sites to WIPP by truck and by commercial rail, using both the TRUPACT-II and a group of alternative packagings, were examined. The results were analyzed to determine if rail shipments are competitive and to provide recommendations for senior management.

The scope of this study was limited to shipments of CH-TRU waste from the following DOE generator/storage sites to the WIPP:

- Rocky Flats Environmental Technology Site (RFETS), Golden, Colorado
- INEEL, Idaho Falls, Idaho
- Hanford, Richland, Washington
- SRS, Aiken, South Carolina.

Other DOE sites were not considered for rail shipments because they either do not have immediate access to rail lines and/or they have a small volume of waste that can be handled economically by truck and do not need the high volume and weight carrying capability of rail (see Table 1).

Table 1: Location and Volume(s) of CH-TRU Waste

Site	Location	Total CH-TRU Waste Projected Through 2033 [3] (cubic meters)	Percentage of Total
LARGE QUANTITY SITES			
Hanford Reservation	Richland, WA	**24,528**	**15.98**
Idaho National Engineering and Environmental Laboratory	Idaho Falls, ID	**76,056**	**49.56**
Los Alamos National Laboratory	Los Alamos, NM	**19,493**	**12.70**
Oak Ridge National Laboratory*	Oak Ridge, TN	**See Small Quantity Sites***	**------**
Rocky Flats Environmental Technology Site	Golden, CO	**15,016**	**9.78**
Savannah River Site	Aiken, SC	**14,235**	**9.28**
SMALL QUANTITY SITES			
Ames Laboratory	Ames, IA	**< 1**	**< 0.01**
ARCO Medical Products	West Chester, PA	**< 1**	**< 0.01**
Argonne National Laboratory-East	Argonne, IL	**246**	**0.16**
Babcock & Wilcox – NES	Lynchburg, VA	**18**	**0.01**
Battelle Columbus Laboratories	Columbus, OH	**4**	**< 0.01**
Bettis Atomic Power Laboratory	West Mifflin, PA	**123**	**0.08**
Energy Technology Engineering Center	Santa Susana, CA	**2**	**< 0.01**
General Electric-Vallecitos Nuclear Center	Pleasanton, CA	**9**	**0.01**
Knolls Atomic Power Laboratory**	Niskayuna, NY	**0**	**0.00**
Lawrence Berkeley Laboratory	Berkeley, CA	**1**	**< 0.01**
Lawrence Livermore National Laboratory	Livermore, CA	**1,515**	**0.99**
Missouri University Research Reactor	Columbia, MO	**1**	**< 0.01**
Mound Plant	Miamisburg, OH	**247**	**0.16**
Nevada Test Site	Nevada	**665**	**0.43**
Oak Ridge National Laboratory*	Oak Ridge, TN	**1,158**	**0.75**
Paducah Gaseous Diffusion Plant	Paducah, KY	**12**	**0.01**
Sandia National Laboratories	Albuquerque, NM	**133**	**0.09**
U.S. Army Material Command	Rock Island, IL	**3**	**< 0.01**
TOTAL		**153,466**	**100.00**

* = Oak Ridge National Laboratory is a small quantity site for CH waste and a large quantity site for remote-handled waste

** = Knolls Atomic Power Laboratory has only remote-handled waste (no CH waste)

[3] U.S. Department of Energy, "The National TRU Waste Management Plan," *DOE/NTP-96-1204*, Rev. 2, Version 9, Carlsbad Area Office, Carlsbad, New Mexico, Draft, July 2000.

4.0 Background

The WIPP facility is located 26 miles southeast of Carlsbad, New Mexico. WIPP was built to serve as the nation's first geological repository for permanent disposal of non-mixed and mixed TRU wastes. TRU waste is currently stored, or will be generated, at 6 major waste-generator sites and 18 small quantity sites listed in Table 1. The DOE estimates that over a 35-year period WIPP could receive approximately 17,000 shipments of CH-TRU waste.[4] The projected number of shipments is expected to increase as sites perform decontamination and decommissioning operations.

The WIPP Land Withdrawal Act (LWA) (Public Law 102-579) was enacted on October 30, 1992. The LWA withdrew the WIPP site from the public domain and transferred the site from the Secretary of the Interior to the Secretary of Energy. The LWA also makes two requirements that are pertinent to this report:

1. "Shipping Containers. -- No transuranic waste may be transported by or for the Secretary *(of Energy)* to or from WIPP, except in packages – the design of which has been certified by the Nuclear Regulatory Commission; and that have been determined by the Nuclear Regulatory Commission to satisfy its quality assurance requirements" [Section 16(a)].

2. "Study of Transportation Alternatives. -- The Secretary *(of Energy)* shall conduct a study comparing the shipment of transuranic waste to the WIPP facility by truck and by rail" [Section 16(f)].

As required by the LWA, a study comparing truck versus rail was issued in 1994[5] and an updated study was issued in 1998[6]. (Note: A list of previous truck/rail reports is included in Appendix B.) The 1994 report was based on the WIPP transportation study completed as part of the Final Supplement Environmental Impact Statement[7] and provided a comparison of three options for transporting waste to the WIPP: by truck, by commercial rail, and by dedicated rail. The 1994 report addressed public risks and exposures, environmental impacts, and emergency

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[4] U.S. Department of Energy, "The National TRU Waste Management Plan," *DOE/NTP-96-1204*, Rev. 2, Version 9, Carlsbad Area Office, Carlsbad, New Mexico, Draft, July 2000.

[5] U.S. Department of Energy, "Comparative Study of Waste Isolation Pilot Plant (WIPP) Transportation Alternatives," *DOE/WIPP 93-058*, Carlsbad Area Office, Carlsbad, New Mexico, February 1994.

[6] U.S. Department of Energy, "WIPP Transportation Assessment Update—Comparative Cost and Risk Assessments," *DOE/WIPP 98-2282*, Carlsbad Area Office, Carlsbad, New Mexico, September 1998.

[7] U.S. Department of Energy, "Final Supplement Environmental Impact Statement Waste Isolation Pilot Plant," *DOE/EIS-0026-FS*, Office of Environmental Restoration and Waste Management, Washington, D.C., 1990.

response capabilities, and concluded that the DOE could safely transport TRU waste to the WIPP facility during the disposal phase but encouraged further study to allow selection of a transportation option. The 1998 report served as a follow-up to the 1994 report and was based on revised volume data from the 1996 National TRU Waste Management Plan[8]. Like the 1994 report, the 1998 report concluded that the shipment of TRU waste to the WIPP does not present any significant risk to the general public or to transportation workers. The 1998 report, however, added that the option of truck shipments holds an advantage over the other two options of rail shipments based on a cost comparison.

Various short reports also supplement the 1994 and 1998 studies. The letter report "TRU Waste Shipment Transportation Mode"[9] completed in 1989 provided reasons for limiting the existing transportation system to truck shipments. The 1989 letter report stated that a rail-based transportation system had not been implemented because of problems with scheduling (shipment schedules not controlled by WIPP personnel for rail shipments), safety/security [possibility of unguarded TRUPACT-II units on rail lines and potential problems with using the Transportation Tracking and Communication System (TRANSCOM) on rail lines], and cost (rail shipment costs exceed truck shipment costs by more than $100 million). A report in September 1996[10] supported the conclusions of the 1989 letter report, adding that a truck-only shipping program is preferred because (1) not all sites have rail access, (2) rail shipments would likely require an increase to the 60-day shipping period due to the potential lack of control over rail shipping schedules and would therefore require the recalculation of gas generation rate limits, consequently affecting the envelope of authorized contents for inclusion in a shipping package, (3) rail shipments would require a larger fleet of packagings, and (4) the use of the HalfPACT packaging would make truck shipments of heavy drums more efficient than use of the TRUPACT-II. A subsequent letter report in July 1997[11] evaluated various packagings for potential use in shipping waste to the WIPP and compared truck and rail shipment options, with a result that rail shipments cost approximately 25% more than truck shipments (the evaluation of

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[8] U.S. Department of Energy, "The National Transuranic Waste Management Plan," *DOE/NTP-96-1204*, Rev.0, Carlsbad Area Office, Carlsbad, New Mexico, September 1996.

[9] Westinghouse Electric Corporation, "TRU Waste Shipment Transportation Mode," Letter Report WD:89:00577, Carlsbad, New Mexico, May 1989.

[10] Westinghouse Electric Corporation, "TRUPACT-II Shipments By Rail Versus Truck," Letter Report HA:96:04650, Carlsbad, New Mexico, September 1996.

[11] Westinghouse Electric Corporation, "Transportation Methods and Costs for Intersite Shipments of Transuranic Waste," Letter Report HA:97:03173, Carlsbad, New Mexico, July 1997.

various packagings in this study, described in Section 6.3 and contained in Appendix C, is based on this July 1997 report). In August 1999, a rail shipment report (not DOE funded) entitled "Rail Shipments to WIPP: Is There a Business Opportunity?"[12] examined the possibility of using rail shipments for large volumes of CH-TRU waste from three large sites after 2004. Alternate packages were considered, and fifteen parameters were varied in a model used for the analysis; however, the report concluded that rail shipments using the TRUPACT-II or HalfPACT packagings did not present a viable business opportunity due to the capital cost of the large additional fleet required.

A Disposal Phase Final Supplemental Environmental Impact Statement[13] was performed for the WIPP in 1997, which evaluated the impact of both truck and rail shipments to the WIPP. Both modes of transport were deemed to be safe. Several of the previous studies, including the 1998 report, compared the relative risk of shipments by truck versus rail and concluded that both systems are safe with minimum risk of exposure to the public or the environment.

In mid-1999, the DOE directed that a re-engineering effort be undertaken to ensure that the pipeline to WIPP will be filled. One area identified for further study by the transportation re-engineering team was the transportation system. Part of the focus on the transportation system included additional study of the use of a rail-based transportation system. This rail study information was also requested by the Environmental Management Program Integration Executive Committee, a committee formed to evaluate opportunities for reduced cost and improved efficiencies through integration. Thus, a team of subject matter experts (SMEs) from the sites was assembled in December 1999 to take a fresh look at the potential use of rail for shipments to the WIPP (a list of the participants is included in Appendix A). The team decided to look at the issue of rail shipments from a new perspective and to address some of the factors those previous studies may not have considered. For example, in this study, unlike previous studies, rail was considered as a supplement to the existing truck transportation system and not just as a replacement. [Previous studies had shown that a rail-only transportation system was not feasible due to the fact that some sites do not have rail access (e.g., Los Alamos National Laboratory and Nevada Test Site).] Also, in this study, the potential benefits that might be derived from new packaging concepts were considered.

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[12] Westinghouse Government Environmental Services, "Rail Shipments to WIPP: Is There a Business Opportunity?", Carlsbad, New Mexico, August 1999.

[13] U.S. Department of Energy, "Waste Isolation Pilot Plant Disposal Phase Final Supplemental Environmental Impact Statement (SEIS-II)," DOE/EIS-0026-S-2, Carlsbad Area Office, Carlsbad, New Mexico, September 1997.

5.0 Study Assumptions

For the purposes of this study of rail-based transportation systems, the following assumptions were made for the four sites evaluated in this study:

- Waste will be certified for disposal prior to shipment
- Characterized and certified waste is available to fill all shipments to volume or weight limits
- The application for Revision 19 of the TRUPACT-II Safety Analysis Report (SAR) will be approved by the NRC and gas generation wattage will not be limiting
- Characterization of large boxes can be accomplished for alternative packaging concepts
- Both truck and rail shipments to WIPP are safe (the conclusions of previous risk assessments, including the 1998 report, are valid)
- The study only considers commercial rail shipments, as dedicated rail shipments are deemed to be too costly (up to $53 per mile)[14] based on previous reports and discussions with rail line representatives
- Rail costs are 25% lower than the values reported in the 1998 cost comparison report for INEEL, Hanford, and SRS, and 45% lower than the values reported in the 1998 report for RFETS[15]
- All legal and regulatory requirements will be satisfied in each option considered (legal and regulatory requirements are addressed in detail in Appendix E).

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[14] U.S. Department of Energy, "WIPP Transportation Assessment Update—Comparative Cost and Risk Assessments," *DOE/WIPP 98-2282*, Carlsbad Area Office, Carlsbad, New Mexico, September 1998.

[15] Based on phone conversations with representatives from Burlington Northern Santa Fe Corporation, it was determined that it should be possible to negotiate at least a 25% reduction from the rates shown in the 1998 report for INEEL, Hanford, and SRS. Consequently, this 25% reduction was used as the basis for rail carriage rates for these three sites. An estimated rate reduction for RFETS was not provided. A scoping analysis, used to determine an appropriate rate reduction for RFETS, showed that a 25% reduction in carriage rates for RFETS did not produce rates that were consistent with the other three sites on a per mile basis. Therefore, a 45% rate reduction, which does provide consistent carriage rates on a per mile basis, was used for RFETS.

6.0 Packagings Considered for Study

A variety of existing packagings, including both currently existing and newly proposed packagings, were reviewed, as addressed in the following sections.

6.1 TRUPACT-II

The TRUPACT-II is designed to hold fourteen 55-gallon drums, two standard waste boxes (SWBs), or one ten-drum overpack. Up to three TRUPACT-IIs may be transported by truck, and up to seven TRUPACT-IIs could be transported per standard railcar. Currently, the TRUPACT-II is only authorized for shipment by truck; shipment of the TRUPACT-II by rail would require a revision to the Certificate of Compliance (C of C). The NRC certified the TRUPACT-II as a Type B packaging in 1989. The current C of C expires in 2004 when a request will be submitted to renew it for an additional five years.

The TRUPACT-II SAR, Appendix 1.3.7, provides specific guidance to the shipper regarding actions required to meet C of C requirements applicable to each waste container and each shipment. By complying with the requirements of Appendix 1.3.7 and the C of C, the shipper would incur no risk of offering a shipment that does not meet U.S. Department of Transportation (DOT) or NRC requirements. For sites where no capability or no procedures exist to load or unload the TRUPACT-II, mobile loading units and approved procedures are available from the WIPP. The DOE currently owns 15 certified TRUPACT-IIs, and contracts are in place to deliver an additional 18 TRUPACT-IIs.

6.2 HalfPACT

A new packaging, the HalfPACT, has been developed to transport heavier-than-average drums of CH-TRU waste. The HalfPACT is a shorter version of the TRUPACT-II. The HalfPACT will have the capability to transport seven 55-gallon drums, one SWB, or four 85-gallon drum overpacks (each 85-gallon drum containing one 55-gallon drum). Up to seven HalfPACTs could be transported per standard railcar. Shipment of the HalfPACT by rail would also have to be incorporated in an application to request revision to the C of C (once the C of C is granted; the HalfPACT SAR is currently under review by the NRC). [Note: Although the HalfPACT is a packaging designed for the shipment of CH-TRU waste, only the TRUPACT-II is used as the baseline for the models used in this study.]

6.3 Other Existing Packagings

A number of existing packagings were considered for use in the supplemental rail transportation system. These packagings are identified and addressed in Appendix C. As shown in Appendix C, none of the existing packagings is economically or logistically competitive for this application.

6.4 LSA Packagings

The definition of low specific activity (LSA) waste is based on the amount of radioactive material and the mass of the waste present, as per the requirements in Title 49, Code of Federal Regulations (CFR), Part 173 (49 CFR 173). Several types of packagings are allowed for the transportation of LSA material, including Type A packagings such as 55-gallon drums. A study conducted by Bild and Weiner[16] evaluated the applicability of LSA shipping provisions to TRU waste. This study concluded that a significant portion (up to 17%) of the TRU waste inventory may meet the requirements for LSA material and significant cost savings could be realized if this TRU waste inventory could be shipped as LSA material. It is true that there is a very narrow band of material that could be shipped as LSA that also meets the definition of TRU; however, to capitalize on this narrow band, refined assay and characterization techniques would need to be developed. In addition, as stated previously, the LWA requires all waste to be shipped to or from the WIPP to be in packages approved by the NRC; however, the NRC does not certify LSA packages. For these reasons, LSA packagings were not considered in this study.

6.5 New Type B Packaging

Because no existing packaging (other than the HalfPACT) proved to be advantageous or competitive with the TRUPACT-II for shipment of CH-TRU waste by rail, a team of SMEs from throughout the complex was recently assembled to define initial concepts for a new Type B packaging capable of shipping TRU waste by rail. The findings from this effort are described in detail in a report compiled by the INEEL[17] and are summarized below.

The study concluded that designing, developing, and fabricating a new Type B packaging for shipping some TRU waste forms to the WIPP by rail or truck conveyance appears to be technically and economically feasible and beneficial. The most attractive use of this new

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[16] Bild, R.W., and R.F. Weiner, "Applicability of Low Specific Activity (LSA) Shipping Provisions to TRU Waste," Sandia National Laboratories, Albuquerque, New Mexico, 2000.

[17] Initial Package Design Concepts, Integrated Product Team (IPT), Summary Report, INEEL/EXT-2000-416, Idaho National Engineering and Environmental Laboratory, Idaho Falls, Idaho, March 2000.

packaging is the possibility of moving boxed waste and large contaminated equipment, such as gloveboxes, without the expense of size reduction or repackaging the waste into drums or SWBs that could then be transported in a TRUPACT-II. This could reduce cost and potential worker exposure. The premise of designing a new Type B packaging for these waste forms is based on the assumption that a characterization system can be developed that would enable the boxed waste to be characterized without opening the boxes. In addition, moving boxed waste or large objects between sites that have rail access could help sites meet closure agreements and possibly accelerate clean up and closure.

In developing concepts for the new packagings to be shipped by truck and/or rail, the study used available information, bounding-type configurations, and input from DOE and the team of SMEs to define fundamental constraints for the new packaging concepts (size limits, weight limits, etc.). (Issues identified as important parameters for authorized contents and their associated impact on packaging evaluation are addressed in Appendix D.) Of eleven packaging options initially identified, five packaging concepts were retained:

> **Concept 1:** *A cylindrical packaging with internal dimensions of 6 feet in diameter and 15 feet in length*. This concept is a longer version of the TRUPACT-II but would hold two 4- by 4- by 7-foot boxes or four stacks of seven drums (28 total drums), with three packages loaded per railcar, or two packages per truck.

> **Concept 2:** *A cylindrical packaging with internal dimensions of 7.5 feet in diameter and 22 feet in length*. This concept is similar to Concept 1 for rail, but is wider and longer to provide for three 5- by 5- by 7-foot boxes, three 4- by 4- by 7-foot boxes, or six stacks of eight drums (48 total drums), with two packages per railcar. This packaging could potentially ship up to 96% of the existing waste boxes.

> **Concept 3:** *A cylindrical packaging with internal dimensions of 6 feet in diameter and 8 feet in length*. Like Concept 1, this packaging is essentially a length extension of the presently used TRUPACT-II that could accommodate the frequently used 4- by 4- by 7-foot TRU waste box. The packaging would hold one 4- by 4- by 7-foot box or two stacks of seven 55-gallon drums (14 total drums), with five packages per railcar, or two packages per truck.

> **Concept 4:** *A rectangular packaging with internal dimensions of 8 feet by 8 feet by 20 feet.* This version for rail shipments would hold up to ten 4- by 4- by 7-foot boxes, or four 5- by 5- by 8-foot boxes, or 72 drums, with two packages per railcar. The concept is similar in many respects to the packages placed in an ATMX railcar and the original TRUPACT-I concept. The edges and corners are assumed rounded for structural integrity.

Concept 5: *A rectangular packaging with internal dimensions of 6 feet by 6 feet by 8 feet*. This concept is a rectangular cross-section packaging that provides for larger box payloads. One 4- by 4- by 7-foot or one 5- by 5- by 8-foot box, or two stacks of nine drums (18 total drums) could be accommodated per packaging, with five packages per railcar, or two packages by truck.

7.0 Evaluation Methodology

Two models were used to evaluate shipments of CH-TRU waste to WIPP by rail. The models were developed independently, used different approaches to reach a solution, and provided results that were typically within the round-off error and at most differed by less than 10%. One notable difference between the two models is the assessment of maintenance cost. The maintenance cost for the Ten-Year Plan Transportation Model (TEPTRAM) is based on an assumption of $200 per use of each TRUPACT-II, whereas the maintenance cost for the WIPP Spreadsheet model (from experience to date) is based on $5,000 per packaging per year for annual inspection, and $100 per use of each TRUPACT-II for routine maintenance (parts and labor). This difference, however, does not appear to affect the conclusion.

7.1 WIPP Spreadsheet

The WIPP Spreadsheet[18], a Microsoft Excel Version 7 for Windows™ spreadsheet, was developed by Westinghouse Government Environmental Services to evaluate potential business opportunities for rail shipment (not DOE funded). Input variables included the following:

- Site (see Section 3.0)
- Volume (cubic meters – see Table 1)
- Loading efficiency (percent of packaging filled with waste)
- Years to complete shipments[19]
- Number of TRUPACT-IIs per shipment
- Round-trip distance (miles)

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[18] Westinghouse Government Environmental Services, “Rail Shipments to WIPP: Is There a Business Opportunity?”, Carlsbad, New Mexico, August 1999.

[19] U.S. Department of Energy, “The National TRU Waste Management Plan,” *DOE/NTP-96-1204*, Rev. 2, Version 9, Carlsbad Area Office, Carlsbad, New Mexico, Draft, July 2000.

- Cost per highway mile (range from $3.00 to $4.00 per mile)[20]
- Cost per rail shipment (75% of costs in 1998 report to reflect potential negotiated price reduction)
- One-way travel time (hours)
- Site turnaround time (hours per shipment)
- WIPP turnaround time (hours)
- Site reserve pool (TRUPACT-IIs)
- WIPP reserve pool (TRUPACT-IIs)
- TRUPACT-II cost.

The spreadsheet model solves for the following:

- Drum equivalent volume
- Required shipping rate to meet schedule
- Drums per shipment (assuming 14 drums per TRUPACT-II maximum)
- Transportation cost per drum
- Fleet size required to meet schedule
- Packaging cost per drum shipped (capital cost of packaging amortized over the time period required to complete shipments)
- Packaging maintenance cost per shipment
- Packaging maintenance cost per year
- Total cost per drum.

The spreadsheet model proved to be a useful tool for evaluating "what-if" scenarios. One example is deciding whether to use a drop-and-pull shipping campaign (the truck arrives at the

[20] The $3.00 per mile figure was projected (assuming full WIPP throughput) from actual carrier contract costs for the period 1995 through 1999. The $4.00 per mile figure was used to evaluate the sensitivity of this parameter.

site with a trailer load of empty TRUPACT-IIs, unloads the empty TRUPACT-IIs, and connects to a waiting trailer with loaded TRUPACT-IIs. This is repeated, in reverse, at WIPP. Thus, the multiple-driver teams are always driving.) An alternative shipping campaign has the drivers waiting while TRUPACT-IIs are loaded and unloaded. In general, drop-and-pull is better for sites with larger volumes and dedicated shipping campaigns, whereas drivers should wait if the site's waste volume is small.

7.2 TEPTRAM

The TEPTRAM transportation cost model[21] was developed by Oak Ridge National Laboratory in support of the DOE Office of Transportation. The model has been used as part of DOE's Ten-Year Planning process, and more recently to support Environmental Management's Accelerating Cleanup – Paths to Closure Plan. It has been benchmarked against other strategic cost estimation models and found to be consistent with costs given by those models.

TEPTRAM estimates the costs of a shipping campaign as a function of time. Campaign-specific information is needed to run the model, along with packaging information and carrier cost in dollars per mile. First, the origin and destination locations are used by the Transportation Routing Analysis Geographical Information System (TRAGIS)[22] to determine transit distance and times. Then the packaging capacity and quantity of material to be transported is used to determine the number of packaged units required to be moved. Turnaround and transit times are used to calculate movement rates, which are then predicted over the duration of the campaign. Any identified constraints, such as limited availability of packages or defined campaign duration, are used to drive the overall system configuration. Costs can then be calculated and summed for each parameter and the complete campaign. Outputs obtainable from TEPTRAM include the following:

- Number of packagings required for campaign
- Number of vehicles needed for campaign
- States and Tribal lands traversed
- Packaging maintenance costs and packaging purchase costs
- Vehicle lease cost (if applicable)

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[21] Michelhaugh, R.D. and R.B. Pope, Ten Year Transportation Model (TEPTRAM), Oak Ridge National Laboratory Transportation Technologies Group. Oak Ridge, Tennessee.

[22] Johnson, P.E. and R.D. Michelhaugh, "Transportation Routing Analysis Geographical Information System (WebTRAGIS) User's Manual," ORNL/TM-2000/86, Oak Ridge National Laboratory, Oak Ridge, Tennessee, 2000.

- Labor cost for loading and unloading
- Management cost for oversight of loading and unloading
- TRANSCOM costs (not used in this study)
- Carriage costs
- Total campaign cost.

8.0 Results

The estimated transportation costs for shipping CH-TRU waste to WIPP from four DOE sites over the scheduled disposal phase are presented in this report. The cost estimates were calculated for both truck and commercial rail transportation. A baseline case that used the TRUPACT-II as the shipping packaging was established. Five additional cases were based on the results from the alternative packaging study referenced in Section 6.5 of this report. Transportation costs include carriage cost, packaging procurement and maintenance, and the loading costs at each site of origin along with the unloading costs at the WIPP. Unloading costs do not include emplacement of the waste into the repository, although emplacement costs would be much the same for all of the options considered. All costs are reported in current dollars.

An evaluation of costs for both truck and rail transportation was performed using TEPTRAM. Results were validated against the WIPP Spreadsheet model, but all results reported in this section are based on the TEPTRAM model.

8.1 Baseline Case (TRUPACT-II): Model Assumptions and Results

The assumptions below were used in the cost calculation for the baseline case:

Common to Both Truck and Rail

- DOE provides shipping packagings

- A TRUPACT-II costs $350,000

- Assume each 55-gallon drum holds 0.208 cubic meters of waste

- Assume each TRUPACT-II holds 2.45 cubic meters of waste (14 drums per TRUPACT-II at a waste packaging efficiency of 85%)

- Assume full availability of packagings

- Maintenance cost is $5,000 per packaging per year, plus a per use cost of $100 (WIPP Spreadsheet)

- Maintenance cost is based on a per use cost of $200 (TEPTRAM)

- Loading time = 8 hours per TRUPACT-II; unloading = 4 hours per TRUPACT-II

- The cost of TRANSCOM to track shipments was not included

- Shipping routes are based on TRAGIS

- Assume shipments begin on October 1, 2002[23]

Specific to Truck

- The carrier cost includes drivers, trailers[24], and tractor
- Trucking equipment maintenance is not separately identified
- Carrier cost is $3.50 per mile (including trucking equipment maintenance)[25]
- Each trailer holds three TRUPACT-IIs

Specific to Rail

- Rail shipment is for commercial (not dedicated) service

- The rail carriage cost used for this study was 75% of the value used in the 1998 cost comparison report, except for RFETS, which was 55% of the value. Lower values from the 1998 report were used to reflect potential negotiated price reductions for multiple shipments.

- Maintenance cost of railcars is not included

- A rail shipment consists of three railcars with six TRUPACT-IIs per railcar

- An expanded volume rail shipment consists of four railcars with seven TRUPACT-IIs per railcar

- Assume no more than 10 days for one-way trip.

The schedule and volumes of waste to be shipped are summarized in Table 2:

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[23] In order to show that a rail system could be implemented, it was necessary to allow sufficient time to develop the necessary infrastructure. Therefore, the date for first shipment in this analysis is October 1, 2002.

[24] Trailers are currently provided by DOE.

[25] Projected cost based on actual carrier contract costs for the period 1995 through 1999.

Table 2: Site Shipping Period Duration and Waste Volumes Used in Study

Site	Schedule (years)	Volume (cubic meters)[26]	Number of Shipments Truck/Rail
INEEL	23	34,962 [a]	4,757/793
Hanford	33	14,417 [a]	1,962/327
RFETS	4	7,770 [b]	1,058/177
SRS	28	19,538 [c]	2,659/444

Note: Volumes in Table 2 do not match Table 1. Differences in volume estimation can be attributed to the following:

[a] Waste volume requiring shipment after 2002 based on waste treatment and volume reduction.

[b] Waste volume requiring shipment after 2002 based on repackaging of residues and assuming a reduced volume due to prior years shipments.

[c] Waste volume requiring shipment after 2002 based on volume expansion of plutonium-238 heat source waste to meet decay heat limits.

Results from the TEPTRAM transportation cost model for the baseline case are summarized by site in Tables 3 through 6 at the end of this section.

The total cost of shipping TRU waste using railroad as the transport mode is slightly higher than shipping by truck for all four sites using the base case assumptions. The difference ranges from 5% at SRS to 16% at RFETS. A sensitivity analysis on truck carriage cost demonstrates that if the carriage cost increases from $3.50 to $4.00 per mile, then the cost difference between the two modes is marginal.

Rail feasibility is enhanced as the volume of waste per shipment is increased. A sensitivity analysis on expanded volume (28 TRUPACT-IIs per shipment, compared with 18 TRUPACT-IIs per shipment – see assumptions under "*Specific to Rail*") demonstrates that rail transport is competitive with truck at both Hanford and SRS. At INEEL, the comparative costs are within 2.6%. The results for RFETS are not improved as you increase the volume on a per-shipment basis. The reason is that the short shipping schedule (only four years) cannot compensate for the additional packaging costs. For the sites with longer shipping schedules, the benefit from shipping larger volumes is that the number of lifecycle shipments is drastically reduced. At INEEL, the number of truck shipments is estimated at 4,757, while with the rail-expanded volume case only 510 shipments would be required. Therefore, total carriage costs decrease with the reduction in the number of shipments. Also, while both truck and rail shipments are safe, reduction in the number of shipments is a desirable factor.

[26] Hamp, S.C., and J.D. Vandekraats, U.S. Department of Energy, Personal Communication, February 2000.

Although volume expansion helps make rail transportation more competitive with truck, it should be noted that expansion beyond 28 TRUPACT-IIs per rail shipment is not practical. This is based on the limitation of the NRC-approved 30-day normal shipping period for the TRUPACT-II. Given that a shipment of TRUPACT-IIs must be loaded, shipped, and unloaded within 30 days, 10 days can be assumed for each activity. Based on an assumption of eight hours to load and leak-test a single TRUPACT-II, a site with two loading stations and two shifts per workday can load and leak-test four TRUPACT-IIs per workday. Allowing for holidays, weekends, and downtime, seven workdays per ten day period provides a total of 28 TRUPACT-IIs that can be loaded in the time allotted for a single shipment. This is the basis for using 28 TRUPACT-IIs per expanded volume shipment as an upper bound. While the number of loading stations could be increased to increase throughput, the number of packages shipped would still be limited by the maximum rate at which the WIPP can receive waste, which is currently 51 TRUPACT-IIs per week.

A consequence of increasing the volume of waste per shipment and decreasing total carriage costs, however, is that a larger packaging fleet is required. For example, shipping by truck from INEEL would require 15 TRUPACT-IIs, while shipping by rail would require 36 TRUPACT-IIs. For the expanded volume case from INEEL, 56 TRUPACT-IIs would be required. The cost of the additional packagings can be offset over the lifecycle of the campaign given sufficient volume of waste to be shipped over time, but increasing fleet size does require a greater capital investment in packaging at the beginning of the shipping campaign.

A cost sensitivity analysis on rail carriage cost was performed as part of this study. Results are summarized in Tables 3 through 6 and demonstrate that when rail carriage costs are negotiated down an additional 16 to 32%, depending on the site, then the total cost for shipping is competitive with the truck mode. This situation is not applicable to RFETS, because the short schedule does not accommodate a competitive rail cost using TRUPACT-II as the shipping packaging. It is anticipated that this range of negotiation is reasonable, given that the initial rail carriage costs for this study were based on values from the 1998 WIPP Transportation Assessment Update and are considered high. The sensitivity analysis was only done for the baseline case and would be even more favorable considering the expanded volume case.

Table 3: Rail Feasibility Results for INEEL Using the TRUPACT-II (TEPTRAM Model)

	Cost in Millions of Dollars		
Item	**Baseline** (18 TRUPACT-IIs per shipment)	**Expanded Volume** (28 TRUPACT-IIs per shipment)	**Cost Sensitivity** (rail total cost equals truck total cost)
Truck Carriage Cost	$46.4		
Rail Carriage Cost	$57.5	$37.0	$39.5
Number of Shipments – Truck	4,757		
Number of Shipments – Rail	793	510	793
Inventory of Packagings - Truck	15		
Inventory of Packagings - Rail	36	56	36
Truck Packaging Cost	$5.0		
Rail Packaging Cost	$11.9	$18.5	
Truck Packaging Maintenance	$2.9		
Rail Packaging Maintenance	$2.9	$2.9	
Subtotal: Truck Packaging and Carriage Cost	**$54.3**		
Subtotal: Rail Packaging and Carriage Cost	**$72.3**	**$58.4**	
Truck Load/Unload Cost	$106.7		
Rail Load/Unload Cost	$106.7	$106.7	
TRUCK TOTALS	**$161.0**		
RAIL TOTALS	**$179.0**	**$165.1**	**$161.0**

Notes:
Expanded Volume refers to a rail shipment of four railcars with seven TRUPACT-IIs per railcar, compared with three railcars with six TRUPACT-IIs per railcar for the baseline case.

For the cost sensitivity data, the baseline case packaging and maintenance costs are held constant, and the rail carriage rate is adjusted to determine the necessary cost to make the rail shipment option competitive with truck shipments.

Packaging Maintenance and Load/Unload Cost are assumed to be the same for all (truck, rail, and expanded volume rail), as costs are based on the total number of packagings.

Table 4: Rail Feasibility Results for RFETS Using the TRUPACT-II (TEPTRAM Model)

	Cost in Millions of Dollars		
Item	**Baseline** (18 TRUPACT-IIs per shipment)	**Expanded Volume** (28 TRUPACT-IIs per shipment)	**Cost Sensitivity** (rail total cost equals truck total cost)
Truck Carriage Cost	$5.2		
Rail Carriage Cost	$3.9	$2.5	Not applicable
Number of Shipments - Truck	1058		
Number of Shipments - Rail	177	114	177
Inventory of Packagings - Truck	15		
Inventory of Packagings - Rail	36	56	36
Truck Packaging Cost	$5.0		
Rail Packaging Cost	$11.9	$18.5	
Truck Packaging Maintenance	$0.6		
Rail Packaging Maintenance	$0.6	$0.6	
Subtotal: Truck Packaging and Carriage Cost	**$10.8**		
Subtotal: Rail Packaging and Carriage Cost	**$16.4**	**$21.6**	
Truck Load/Unload Cost	$23.8		
Rail Load/Unload Cost	$23.8	$23.8	
TRUCK TOTALS	**$34.6**		
RAIL TOTALS	**$40.2**	**$45.4**	**Not applicable**

Notes:
Expanded Volume refers to a rail shipment of four railcars with seven TRUPACT-IIs per railcar, compared with three railcars with 6 TRUPACT-IIs per railcar for the baseline case.

For the cost sensitivity data, the baseline case packaging and maintenance costs are held constant, and the rail carriage rate is adjusted to determine the necessary cost to make the rail shipment option competitive with truck shipments. For RFETS, rail carriage costs cannot be reasonably lowered enough to make rail option competitive with truck (represented by “Not applicable” in Cost Sensitivity column).

It should be noted that packages could be used at other sites after RFETS closure to reduce lifecycle package cost.

Packaging Maintenance and Load/Unload Cost are assumed to be the same for all (truck, rail, and expanded volume rail), as costs are based on the total number of packagings.

Table 5: Rail Feasibility Results for Hanford Using the TRUPACT-II (TEPTRAM Model)

	Cost in Millions of Dollars		
Item	**Baseline** (18 TRUPACT-IIs per shipment)	**Expanded Volume** (28 TRUPACT-IIs per shipment)	**Cost Sensitivity** (rail total cost equals truck total cost)
Truck Carriage Cost	$24.8		
Rail Carriage Cost	$26.7	$17.2	$20.9
Number of Shipments - Truck	1,962		
Number of Shipments - Rail	327	211	327
Inventory of Packagings – Truck	6		
Inventory of Packagings – Rail	18	28	18
Truck Packaging Cost	$2.0		
Rail Packaging Cost	$5.9	$9.2	
Truck Packaging Maintenance	$1.2		
Rail Packaging Maintenance	$1.2	$1.2	
Subtotal: Truck Packaging and Carriage Cost	**$28.0**		
Subtotal: Rail Packaging and Carriage Cost	**$33.8**	**$27.6**	
Truck Load/Unload Cost	$44.1		
Rail Load/Unload Cost	$44.1	$44.1	
TRUCK TOTALS	**$72.1**		
RAIL TOTALS	**$77.9**	**$71.7**	**$72.0**

Notes:

Expanded Volume refers to a rail shipment of four railcars with seven TRUPACT-IIs per railcar, compared with three railcars with six TRUPACT-IIs per railcar for the baseline case.

For the cost sensitivity data, the baseline case packaging and maintenance costs are held constant, and the rail carriage rate is adjusted to determine the necessary cost to make the rail shipment option competitive with truck shipments.

Packaging Maintenance and Load/Unload Cost are assumed to be the same for all (truck, rail, and expanded volume rail), as costs are based on the total number of packagings.

Table 6: Rail Feasibility Results for SRS Using the TRUPACT-II (TEPTRAM Model)

	Cost in Millions of Dollars		
Item	**Baseline** (18 TRUPACT-IIs per shipment)	**Expanded Volume** (28 TRUPACT-IIs per shipment)	**Cost Sensitivity** (rail total cost equals truck total cost)
Truck Carriage Cost	$28.7		
Rail Carriage Cost	$30.7	$19.7	$25.8
Number of Shipments - Truck	2,659		
Number of Shipments - Rail	444	285	444
Inventory of Packagings - Truck	9		
Inventory of Packagings - Rail	18	28	18
Truck Packaging Cost	$3.0		
Rail Packaging Cost	$5.9	$9.2	
Truck Packaging Maintenance	$1.6		
Rail Packaging Maintenance	$1.6	$1.6	
Subtotal: Truck Packaging and Carriage Cost	**$33.3**		
Subtotal: Rail Packaging and Carriage Cost	**$38.2**	**$30.5**	
Truck Load/Unload Cost	$59.6		
Rail Load/Unload Cost	$59.6	$59.6	
TRUCK TOTALS	**$92.9**		
RAIL TOTALS	**$97.8**	**$90.1**	**$92.9**

Notes:
Expanded Volume refers to a rail shipment of four railcars with seven TRUPACT-IIs per railcar, compared with three railcars with six TRUPACT-IIs per railcar for the baseline case.

For the cost sensitivity data, the baseline case packaging and maintenance costs are held constant, and the rail carriage rate is adjusted to determine the necessary cost to make the rail shipment option competitive with truck shipments.

Packaging Maintenance and Load/Unload Cost are assumed to be the same for all (truck, rail, and expanded volume rail), as costs are based on the total number of packagings.

8.2 Alternative Packaging Case: Model Assumptions and Results

The assumptions below were used in the transportation cost calculation for the alternative packaging design concepts (refer to Section 6.5 for descriptions of packagings):

Common to Both Truck and Rail (Same as for the baseline case, except as noted)

- Alternative packaging concepts 1, 2, and 3: procurement cost = $500,000; Maintenance cost = $25,000 per packaging per year
- Alternative packaging concepts 4 and 5: procurement cost = $750,000; Maintenance cost = $25,000 per packaging per year

Specific to Truck

- Alternative concept 1:
  - Each trailer holds 2 packages (6 feet in diameter by 15 feet) at 85% efficiency (24 drums/package)
  - Each package holds 5 cubic meters of waste

- Alternative concept 2: no truck shipment considered (package is too wide for a standard truck and oversize truck shipments would not be cost effective or practical)

- Alternative concept 3:
  - Each trailer holds 2 packages (6 feet in diameter by 8 feet) at 85% efficiency (12 drums/package)
  - Each package holds 2.5 cubic meters of waste

- Alternative concept 4: no truck shipment considered (as noted in concept 2)

- Alternative concept 5:
  - Each trailer holds 2 packages (6 feet by 6 feet by 8 feet) at 85% efficiency (15 drums/package)
  - Each package holds 3.12 cubic meters of waste

Specific to Rail

- Alternative concept 1:
    - Each railcar holds 3 packages, same efficiency as truck
    - Assume each package holds 5 cubic meters of waste
    - A rail shipment consists of 3 railcars (9 packages)

- Alternative concept 2:
    - Each railcar holds 2 packages (7.5 feet in diameter by 22 feet) at 90% efficiency (43 drums/package)
    - Assume each package holds 9 cubic meters of waste
    - A rail shipment consists of 3 railcars (6 packages)

- Alternative concept 3:
    - Each railcar holds 5 packages, same efficiency as truck
    - Assume each package holds 2.5 cubic meters of waste
    - A rail shipment consists of 3 railcars (15 packages)

- Alternative concept 4:
    - Each railcar holds 2 packages (8 feet by 8 feet by 20 feet) at 90% efficiency (65 drums/package)
    - Assume each package holds 14 cubic meters of waste
    - A rail shipment consists of 3 railcars (6 packages)

- Alternative concept 5:
    - Each railcar holds 5 packages, same efficiency as truck
    - Assume each package holds 3.12 cubic meters of waste
    - A rail shipment consists of 3 railcars (15 packages).

The schedule and volume of waste is the same as for the baseline case.

Table 7 provides a summary comparison of rail and truck costs for the TRUPACT-II and alternative packaging options for the four DOE sites involved in this study.

Table 7: Rail and Truck Cost Comparisons for Four Sites and Six Packagings (TEPTRAM Model)

	Millions of Dollars							
	INEEL to WIPP		Hanford to WIPP		RFETS to WIPP		SRS to WIPP	
	Truck	Rail	Truck	Rail	Truck	Rail	Truck	Rail
Baseline Case (TRUPACT-II)								
Packaging and Carriage	$51.4	$69.4	$26.8	$32.6	$10.2	$15.8	$31.7	$36.6
Packaging Use	$109.6	$109.6	$45.3	$45.3	$24.4	$24.4	$61.2	$61.2
TOTAL COST	**$161.0**	**$179.0**	**$72.1**	**$77.9**	**$34.6**	**$40.2**	**$92.9**	**$97.8**
Alternative Concept 1								
Packaging and Carriage	$38.1	$65.4	$19.2	$38.6	$6.8	$12.8	$23.1	$34.6
Packaging Use	$53.4	$53.4	$22.1	$22.0	$11.9	$11.9	$39.8	$39.9
TOTAL COST	**$91.5**	**$118.8**	**$41.3**	**$60.6**	**$18.7**	**$24.7**	**$62.9**	**$74.5**
Alternative Concept 2								
Packaging and Carriage	N/A	$53.5	N/A	$31.6	N/A	$9.2	N/A	$28.3
Packaging Use	N/A	$30.0	N/A	$12.4	N/A	$6.8	N/A	$16.8
TOTAL COST	**N/A**	**$83.5**	**N/A**	**$44.0**	**N/A**	**$16.0**	**N/A**	**$45.1**
Alternative Concept 3								
Packaging and Carriage	$75.1	$90.2	$38.5	$48.3	$14.7	$19.5	$46.1	$51.1
Packaging Use	$106.9	$106.9	$44.0	$44.2	$23.7	$23.9	$59.8	$59.9
TOTAL COST	**$182.0**	**$197.1**	**$82.5**	**$92.5**	**$38.4**	**$43.4**	**$105.9**	**$111.0**
Alternative Concept 4								
Packaging and Carriage	N/A	$34.8	N/A	$22.7	N/A	$6.5	N/A	$20.6
Packaging Use	N/A	$19.1	N/A	$7.9	N/A	$4.3	N/A	$10.7
TOTAL COST	**N/A**	**$53.9**	**N/A**	**$30.6**	**N/A**	**$10.8**	**N/A**	**$31.3**
Alternative Concept 5								
Packaging and Carriage	$63.6	$72.2	$32.2	$40.8	$15.1	$30.7	$38.3	$37.6
Packaging Use	$85.6	$85.7	$35.4	$35.3	$19.1	$19.1	$47.8	$47.8
TOTAL COST	**$149.2**	**$157.9**	**$67.6**	**$76.1**	**$34.2**	**$49.8**	**$86.1**	**$85.4**

Notes:
The Baseline Case is for three railcars with six TRUPACT-IIs per railcar; this does not show the expanded volume case.

Packaging Use = Packaging Maintenance + Packaging Load/Unload (which is roughly the same for a given packaging at a given site – differences are due to rounding of model results).

See Section 6.5, New Type B Packaging, for a description of Alternative Concepts.

Total transportation costs are reduced from the baseline for both the truck and rail modes when a larger volume packaging is used. This is most evident with alternative packaging concept 1 and is somewhat evident in concept 5, with the difference being that alternative packaging concept 5 is more costly to procure than concept 1. The cost reduction is greatest when the largest volume packaging is tied to rail, as seen in alternative packaging concepts 2 and 4. Consequently, the number of shipments per year goes down considerably. For example, at INEEL, the number of rail shipments would be approximately 28 per year, as compared to 35 when shipping by rail with TRUPACT-IIs. The reduction is even greater for alternative packaging concept 4, where only 18 shipments per year would be required. This concept holds for the other three sites as well. Another benefit of larger volume packagings is that the packaging fleet would be smaller, and, therefore, the initial packaging investment would also be smaller. Alternative packaging concept 3 proved to be more expensive for both truck and rail transportation modes than the TRUPACT-II but would provide the capability to ship larger boxes of waste, such as the 4- by 4- by 7-foot box.

8.3 Summary of Results

The following bullets summarize the results of the transportation cost estimates for rail and truck shipments from four DOE sites to WIPP:

Baseline Case

- The difference in cost between truck and rail shipments at the four sites in this study is not as large as indicated in the 1998 assessment report (assuming lower costs are negotiated).

- When rail is used for expanded volumes in the baseline case (shipment in the TRUPACT-II), it is cost effective for Hanford and SRS. The cost difference at INEEL was 2.6%.

- Rail is competitive with truck for the baseline case, normal volume, if rail carriage costs are negotiated down 19 to 32% from the figures shown on Tables 3 through 6, depending on the site[27]. These lower rail carriage rates may be an achievable target given the high level of rail rates from previous studies used as a reference, and the projected level of shipment activity from these sites. If lower rates were negotiated for RFETS, an additional consideration is the fact that the TRUPACT-IIs that would be dedicated to the RFETS rail system would be available for other sites use after RFETS closure in 2006.

[27] Rail carriage costs shown in Tables 3 through 6 are 25 to 45% lower than the values in the 1998 cost comparison report.

- For rail to be feasible it requires a larger volume of waste per shipment than truck shipments and consequently, a larger packaging fleet size. The lifecycle volume shipped at each origin site, except RFETS, financially offsets the initial packaging cost.

- There is a benefit of having fewer shipments made to WIPP. The environmental impacts and risk are low for both truck and rail but fewer shipments and, consequently, potentially lower impacts can be realized from rail.

Alternative Packaging Case

- Transportation costs are reduced for both truck and rail when a larger volume packaging is used.

- The cost reduction is greatest when the largest volume packagings are tied to using the rail mode.

- The comparisons of alternative packagings with the TRUPACT-II assume waste packaged in drums. The alternative packagings were sized to allow shipment of boxed CH-TRU waste. Considering movement of boxed waste, both the moderate-size alternative packagings and large alternative packagings would show reduced costs when compared with the baseline case (using the TRUPACT-II) due to the avoided cost of size reduction and/or repackaging of boxed wastes that would otherwise be necessary to fit the waste into a payload container approved for use in the TRUPACT-II. This cost saving was not quantified as part of this study.

9.0 Conclusions

For the baseline case of shipping CH-TRU waste in the TRUPACT-II packaging, this study concludes that shipment by rail may be competitive if the following conditions can be satisfied:

1. A competitive rail carriage rate (i.e., less than the values in this report) is negotiated

2. A larger fleet of packagings is established

3. The volume of waste per shipment is large enough to reduce the number of shipments and, consequently, offset the cost of the necessary packaging fleet expansion.

This study also concludes that the use of alternative packaging concepts is potentially advantageous in shipping CH-TRU waste to WIPP. Transportation costs are reduced for both truck and rail when a larger volume packaging is used, and the cost reduction is greatest when the largest volume packagings are tied to the rail mode. A higher cost for design and fabrication was identified but is offset based on the reduction in the total number of shipments required. In addition, there is a recognized potential for significant savings if a new shipping packaging were developed for boxed waste or oversize payload containers that would otherwise have to be repackaged and/or size reduced to fit into either the TRUPACT-II or the HalfPACT.

10.0 Recommendations

Based on current information, use of commercial rail[28] for transportation of CH-TRU waste from INEEL, Hanford, RFETS, and SRS to the WIPP site in TRUPACT-IIs can not be recommended at this time for the following reasons:

- The cost analysis is based on an assumed negotiated lower carriage cost
- Although the cost of rail transportation is found to be comparable to truck, there is not a sufficient cost differential to recommend rail
- Rail does not have the schedule flexibility associated with truck shipments (particularly in servicing small quantity sites)
- The cost of developing a rail infrastructure (while not part of this report) may be considerable.

However, because the conclusions show that commercial rail shipments may be competitive for a given set of conditions, the study supports the following recommendations for further study and evaluation of rail shipment options (if these recommendations are accepted, a cost and schedule for implementation could be developed):

1. Develop a strategy to negotiate lower rail costs (commercial and dedicated) for transport of CH-TRU waste to WIPP. This strategy might be developed on a site-by-site basis since there are separate rail lines serving individual sites.
2. Investigate the necessary infrastructure to handle rail shipments (e.g., upgrading rail systems, loading and offloading of TRUPACT-IIs from railcars, emergency preparedness) to help establish an acceptable carriage rate.
3. Continue development of an alternative shipping package for CH-TRU waste for either rail or truck shipment.

[28] Shipment of CH-TRU waste in TRUPACT-II packagings by dedicated rail is not cost effective, based on information from previous reports and discussions with rail line representatives (see Section 5.0, Study Assumptions).

APPENDIX A
LIST OF RAIL STUDY PARTICIPANTS

APPENDIX A

List of Rail Study Participants

Co-Chairs:	Mona Williams, DOE-Albuquerque Operations Office Ines Triay, DOE-Carlsbad Area Office
Members:	Phil Altomare, DOE-Headquarters Tracy Mustin, DOE-Headquarters Lynne Wade, DOE-Headquarters Steve Hamp, DOE-Albuquerque Operations Office Ralph Smith, DOE-Carlsbad Area Office Frank Holmes, DOE-Idaho Operations Office Jerry Wells, DOE-Idaho Operations Office Kevin Blackwell, Federal Railroad Administration Rick Fawcett, Bechtel BWXT Idaho Dale Luke, Bechtel BWXT Idaho John Moss, Bechtel BWXT Idaho Phil Gregory, Westinghouse-Waste Isolation Division Farok Sharif, Westinghouse-Waste Isolation Division Jeff Winkel, Westinghouse-Waste Isolation Division

APPENDIX B
PREVIOUS TRUCK/RAIL REPORTS

APPENDIX B

Previous Truck/Rail Reports

1. TRU Waste Shipment Transportation Mode, Letter Report WD:89:00577, Westinghouse Electric Corporation, Carlsbad, NM, May 1989.

2. Comparative Study of Waste Isolation Pilot Plant (WIPP) Transportation Alternatives, DOE/WIPP 93-058, U.S. Department of Energy, Carlsbad, NM, February 1994.

3. TRUPACT-II Shipments By Rail Versus Truck, Letter Report HA:96:04650, Westinghouse Electric Corporation, Carlsbad, NM, September 1996.

4. Transportation Methods and Costs for Intersite Shipments of Transuranic Waste, Letter Report HA:97:03173, Westinghouse Electric Corporation, Carlsbad, NM, July 1997.

5. Waste Isolation Pilot Plant Disposal Phase Final Supplemental Environmental Impact Statement (SEIS-II), DOE/EIS-0026-S-2, U.S. Department of Energy, Carlsbad Area Office, Carlsbad, NM, September 1997.

6. WIPP Transportation Assessment Update – Comparative Cost and Risk Assessments, DOE/WIPP 98-2282, U.S. Department of Energy, Carlsbad Area Office, Carlsbad, NM, September 1998.

7. Rail Shipments to WIPP: Is There a Business Opportunity?, Westinghouse Government Environmental Services, Carlsbad, NM, August 1999.

APPENDIX C

EXISTING PACKAGINGS CONSIDERED FOR WIPP SHIPMENTS

APPENDIX C

Existing Packagings Considered for WIPP Shipments

The following existing packagings (other than the TRUPACT-II) were identified for potential use in the supplemental rail transportation system. In addition to this list, the TRUPACT-II was evaluated as the baseline for the study, as addressed in Section 6.1 of the report. Each of the following packagings was determined to be either insufficient to meet the requirements for supplemental rail transportation or inferior to the TRUPACT-II, and therefore not considered in the final cost analysis. The reasons for not considering each packaging are addressed individually in the text below. Table C-1 presents a summary of each of the packagings:

Table C-1: Summary of Existing Packagings

Model	Package Number	55-Gal. Drum Capacity	Max. Gross Weight (lbs)	Fissile Pu Quantity	Limit on Hydrogen Gas	Pu > 20 Ci
ATMX 600	DOT-E 5948	140	101,300	2,000 g	6.3 watts	Yes
B-3	USA/6058/B( )F	1	30,000	200 g	0	No
6400	USA/6400/B( )F	12	45,000	60 – 200 g	Heat-sealed bags or Decon Metal	No
CNS 10-160B	USA/9204/B(U)-85	10	72,000	2,000 x A_2 quantity	5%	No
CNS 8-120B	USA/9168/B(U)	8	74,000	2,000 x A_2 quantity	5%	No
N-55	USA/9070/B(U)	1	750	0	3 watts	No
2000	USA/9228/B(U)F	2	33,550	0	5%	No
125-B	USA/9200/B(M)F	15	181,500	0	5%	No
Croft 2917C	N/A	1	8,340	350 g	5% (assumed)	Yes

Notes:

lbs	=	pounds
g	=	grams
A_2	=	maximum activity of radioactive material (other than special form, LSA, and surface contaminated object material) permitted in a Type A package
Pu	=	plutonium
Ci	=	curie
N/A	=	not applicable (no NRC or DOT number)

C.1 ATMX 600

Description

The ATMX 600 is a specially designed steel railcar with a bolted-on steel cover and an interior compartmentalized by steel frames. Closed steel boxes or bins are positioned and shored in each compartment, and internal packagings are placed in the boxes or bins. Internal packagings used with the ATMX 600 satisfy DOT Specification 7A performance standards, with steel as the external packaging material. In the current inventory of packagings, ATMX 600 railcars are fitted to either transport a maximum of 20 metal crates or a maximum of 140 55-gallon drums.

Status

The ATMX 600 is a DOT-exempted packaging, recently authorized for the shipment of TRU waste from the Mound Laboratory in Miamisburg, Ohio, with an exemption expiration of May 31, 2002. There is no C of C with the NRC for the ATMX 600.

Conclusion

As the ATMX 600 is only a DOT-exempted packaging and has not been approved by the NRC, it cannot be used for shipments to the WIPP, as agreed by the State of New Mexico and the DOE. Use of the ATMX 600 to ship to the WIPP site would only be possible if the LWA is changed to allow such packages to be used. For this reason, the ATMX 600 does not meet the requirements for supplemental rail transportation and is not considered a candidate for shipments.

C.2 B-3

Description

The B-3 is a Type B lead-shielded steel cylinder, with internal dimensions of 26½ inches in diameter and 43¼ inches in height. As such, it can only be used for transport of a single 55-gallon drum.

Status

The B-3 has a current NRC C of C (Certificate Number 6058, Revision Number 13) with an expiration date of December 31, 2000. However, fabrication of additional packagings is not authorized per Section 11 of the C of C.

Conclusion

Use of the B-3 packaging for TRU waste shipments would require approximately $2,000,000 to $3,000,000 to redesign and upgrade the B-3, perform required testing, develop a new safety analysis report, and have the NRC review the documentation and issue a revised C of C that includes the "-85"designation [a designation indicating compliance with the 1985 International Atomic Energy Agency (IAEA) transportation requirements, without which future packaging fabrication is prohibited by the NRC]. Considering the above costs, and the fact that only one drum can be transported per shipment, this packaging is considered not to be competitive with the TRUPACT-II.

C.3 6400

Description

The 6400 (also referred to as the "Super Tiger") packaging is a protective overpack that provides impact and thermal protection for contents. Internal dimensions of the packaging are approximately 76 inches by 76 inches by 172 inches. Many waste forms that may be transported in the 6400 packaging must be packaged in heat-sealed bags. If 55-gallon drums are used, the drums must be placed in specially-designed wood or metal boxes prior to loading in the packaging, and the void spaces in the boxes must be filled with foam. A maximum of 12 drums may be shipped in a 6400 packaging.

Status

The 6400 packaging has a current NRC C of C (Certificate Number 6400, Revision Number 25) with an expiration date of July 31, 2002.

Conclusion

Historically, DOE sites packaged their TRU waste in plastic bags and closed the bags using the twist-and-tape method. Due to the waste repackaging that would be required to heat-seal all bags and comply with the C of C requirements, this packaging is not considered to be a candidate for shipments.

C.4 CNS 10-160B

Description

The CNS 10-160B is a carbon steel and lead-shielded cylindrical shipping cask. Internal dimensions of the packaging are 68 inches in diameter and 77 inches in height. A maximum of

10 drums could be shipped in one cask. The cask was designed, tested, and certified as a Type B package.

Status

The CNS 10-160B has a current NRC C of C (Certificate Number 9204, Revision Number 5) with an expiration date of October 31, 2005.

Conclusion

Because of the smaller capacity of the cask (10 drums compared to 14 drums in a TRUPACT-II), this cask is not considered to be competitive with the TRUPACT-II.

C.5 CNS 8-120B

Description

The CNS 8-120B is a carbon steel and lead-shielded cylindrical shipping cask. Internal dimensions of the packaging are 62 inches in diameter and 75 inches in height. A maximum of eight drums could be shipped in one cask.

Status

The CNS 8-120B has an NRC C of C (Certificate Number 9168) that expired as of June 30, 2000.

Conclusion

Because of the smaller capacity of the cask (8 drums compared to 14 drums in a TRUPACT-II), this cask is not considered to be competitive with the TRUPACT-II.

C.6 N-55

Description

The N-55 is a cylindrical overpack with a galvanized steel outer shell, a fiberglass inner shell, and rigid polyurethane foam between shells. The packaging internal dimensions are 24 inches in diameter and 34½ inches in height, with a capacity for one 55-gallon drum.

Status

The N-55 has a current NRC C of C (Certificate Number 9070, Revision Number 14) with an expiration date of January 31, 2005.

Conclusion

Considering the fact that only one drum can currently be transported in the packaging, this packaging is not considered to be competitive with the TRUPACT-II.

C.7 2000

Description

The 2000 (also referred to as the GE Model 2000 packaging) is a steel-encased lead shielded shipping cask. The cask is constructed of two concentric one-inch thick stainless steel cylindrical shells, with the annulus filled with four inches of lead shielding. Internal dimensions of the cask are approximately 26.5 inches in diameter and 54.0 inches in height. Capacity of the cask is two 55-gallon drums.

Status

The 2000 has an NRC C of C (Certificate Number 9228) that expired as of June 30, 1999.

Conclusion

The cost to purchase a GE Model 2000 packaging and all ancillary equipment is $2,000,000. For leasing, there is a one-time $27,500 cask immobilization fee for each cask leased, and leasing costs vary from $1,000 per day to $2,500 per day, depending on the length of the lease. Because this cask only carries up to two drums, it is not considered to be competitive with the TRUPACT-II, and is not considered practical for shipments to WIPP.

C.8 125-B

Description

The 125-B is a stainless steel and lead shielded cylindrical shipping cask. Internal dimensions are a 51.25-inch diameter and a 192.5-inch length. The 125-B was designed to carry seven 14.5-inch inner diameter pipes, but could be redesigned to carry up to 15 drums.

Status

The 125-B has a current NRC C of C (Certificate Number 9200, Revision 9) with an expiration date of April 1, 2001.

Conclusion

Considering the level of effort and time that it would take to redesign the packaging to accommodate 55-gallon drums (conduct tests, develop revisions to the safety analysis report, etc.) and only a slightly larger drum-carrying capacity, this packaging is not considered to be competitive with the TRUPACT-II for transportation of TRU waste.

C.9 Croft 2917C

Description

The Croft 2917C is a double-contained, general-purpose Type B fissile package designed to meet 10 CFR and IAEA regulations. The internal dimensions are 40 inches in diameter by 60 inches high. When the plutonium content exceeds 20 curies, a second containment vessel can be added.

Status

The package has not been certified to meet DOT and NRC requirements, but has been tested and certified to IAEA regulations and can be further certified to meet additional requirements. Manufacturers of the Croft 2917C believe that the users should incur the cost of NRC certification. Therefore, if DOE believes that the use of this packaging is a viable option for single-drum shipments, funding would be required for NRC certification of this package.

Conclusion

Considering that the cost of NRC certification would need to be provided by DOE and the fact that the Croft 2917C only carries a single drum, this cask is not considered to be competitive with the TRUPACT-II.

APPENDIX D

AUTHORIZED CONTENT PARAMETERS USED IN EVALUATION OF SHIPPING PACKAGINGS

APPENDIX D

Authorized Content Parameters Used in Evaluation of Shipping Packagings

The authorized contents within the transportation package selected will be defined and limited by certain key parameters in order to ensure safe transportation conditions. These parameters, as related to CH-TRU waste, are discussed below.

Size: The size of the authorized payload will be dictated by the dimensions and volume capacity of the package selected. The CH-TRU waste inventory ranges in size from 55-gallon drums to oversized boxes greater than 5 feet by 5 feet by 8 feet.

Weight: The design of the packaging will impose restrictions on the weight of both the individual containers as well as the total payload, which limits the number of containers that can be transported per shipment. For truck shipments, there is an 80,000-pound limit (without overweight permit) while rail shipments typically can carry much heavier payloads (e.g., 260,000 pounds per railcar).

Fissile Mass: The TRU waste inventory is predominantly contaminated with plutonium-239, a fissile isotope. Restrictions on the amount of fissile mass per package will limit the payload per container and shipment and may require repackaging if limits are exceeded. Typically, a limit of 200 grams of fissile mass is imposed per 55-gallon drum. For the TRUPACT-II, the entire payload is limited to 325 fissile grams (or 2,800 fissile grams for a payload of pipe overpacks only).

Thermal Wattage: The thermal wattage of the package is limited to control the maximum temperatures in the package as well as to control potential gas generation. For example, the TRUPACT-II has a design limit of 40 watts, with each payload container further limited based on flammable gas generation.

Curie Limits: Individual curie limits, in addition to wattage and fissile limits, may be imposed based on dose rate considerations and the packaging design. According to 10 CFR 71.63(b), "Plutonium in excess of 0.74 TBq (20 Ci) per package must be packaged in a separate inner container placed within outer packaging…" This is frequently referred to as double-containment.

Hydrogen Gas Generation: NRC-approved Type B packages are restricted to $\leq$5% hydrogen concentration (by volume) in the headspaces and innermost containers during transportation of organic material, such as TRU waste, with individual gas generation limits imposed by the package C of C. Because the primary mechanism for hydrogen gas generation in TRU wastes is radiolysis, this can limit the amount of radioactive material that can be shipped per package.

Pressure: The design pressure of the package may limit the amount of gas generation during transportation, which in turn may limit the radioactive material per shipment. The TRUPACT-II, for example, has a design pressure limit of 50 pounds per square inch gauge. Radiolysis of the waste materials and the waste packaging materials (e.g., plastic bags) results in gas generation, which contributes to the pressure increase in the package. The shipping period (discussed below) is an important variable in determining compliance with the design pressure limit of the packaging.

Shipping Period: Pressure calculations are generally performed assuming a one-year shipping period. The NRC allows flammable gas generation calculations to be performed using a smaller time period if it can be justified by the use of dedicated tracking systems. The TRUPACT-II, for example, incorporates a maximum shipping period of 60 days into pressure and flammable gas concentration calculations. Rail shipments are expected to have longer shipping periods compared to truck shipments.

APPENDIX E

LEGAL AND INSTITUTIONAL ISSUES OR REQUIREMENTS

APPENDIX E

Legal and Institutional Issues or Requirements

The following legal requirements and institutional issues are applicable for packaging used to transport TRU waste to the WIPP, and are used as essential requirements in this study:

Transportation of TRU Waste to WIPP

(From 49 CFR 173, Subpart I, Radioactive Material.) In summary, the DOT requires that shipments of plutonium (the primary isotope found in TRU waste) in excess of 5.41×10^{-3} curies be shipped in a Type B packaging that has been approved by the NRC. The DOE is also granted the authority to approve Type B packaging for shipment of DOE radioactive material. However, the DOE signed an agreement with the State of New Mexico that requires,

"All waste shipped to WIPP will be shipped in packages which the Nuclear Regulatory Commission has certified for use."[29]

Also, the LWA requires an NRC-certified package for shipments to WIPP. Therefore, any packaging proposed for use in the transportation of TRU waste to WIPP by rail or by truck must be approved by the NRC.

Safety Analysis

(From 10 CFR 71, Packaging.) The NRC requires a SAR to demonstrate that the packaging design is safe. The SAR evaluates, by test or analysis, containment, subcriticality, and shielding under a variety of normal conditions of transport and hypothetical accident conditions.

DOE Orders

DOE Order 460.1 allows DOE contractors the use of packaging that has been certified by the NRC.

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[29] First Modification to the July 1, 1989 "Agreement for Consultation and Cooperation" on WIPP by the State of New Mexico and the U.S. Department of Energy, signed August 4, 1987.

Transportation System and Protocols

The DOE has developed a transportation system and protocols for the safe and uneventful transportation of transuranic waste by truck in cooperation with the Western Governors' Association, the Southern States Energy Board, the Mid-Western Council of Governors, and various Indian Tribes. The system involves an elaborate process of training, testing and oversight of WIPP transportation. An assumption of the study is that shipments by rail would satisfy requirements for each of the following principal components of the transportation system and protocols:

- High Quality Rail Personnel
- Evidence of Carrier Compliance
- Independent Inspections
- Bad Weather and Rail Conditions
- Safe Parking During Abnormal Conditions
- Advance Notice of WIPP Shipments
- Shipment Status Information
- Medical Preparedness
- Mutual Aid Agreements
- Emergency Response Plans and Procedures
- Emergency Response Equipment
- Training, Exercises
- Public Information and Participation
- Routing of WIPP Shipments
- Program Evaluation.

Agreement with Western Governors Association

A Memorandum of Agreement Between the Western States and the DOE titled, "Regional Protocol for the Safe Transportation of Transuranic Waste to the Waste Isolation Pilot Plant," was signed by the Secretary of Energy and approved by the Western Governors, December 1, 1995. The agreement affirms the involvement of the governors in the development of a safe and uneventful transportation system for the shipment of transuranic waste to the WIPP.

Emergency Response Training

The LWA makes requirements regarding Accident Prevention and Emergency Preparedness [Section 16(c)] and Transportation Safety Programs [Section 16(d)]. The training programs that are currently in place for highway shipments could be modified for rail shipments within the time required to build the additional fleet required for rail shipments.